Southwest Research Institute™

APBF-DEC EGR+DPF+SCR

Update on Progress of APBF-DEC EGR/DPF/SCR Demonstration Program at SwRI

Presented by: Magdi Khair, Chris Sharp

Southwest Research Institute

DEER Conference - San Diego, CA - September, 2004

APBF-DEC

Objectives

- To demonstrate the low emissions performance of advanced diesels + urea SCR + DPF (two different systems)
- To determine the regulated and unregulated emissions with and without emission controls
- To examine the emission control system durability over 6,000 hours
- To sample toxic emissions for analysis by outside lab
- To evaluate sensitivities of the control system performance to fuel variables

Emissions Goals: 2007 EPA HDE Standards

Participating Companies/Organizations

Automobile:
DaimlerChrysler
Ford
GM
Toyota

Government:
CARB/SCAQMD
DOE
EPA
NREL
ORNL

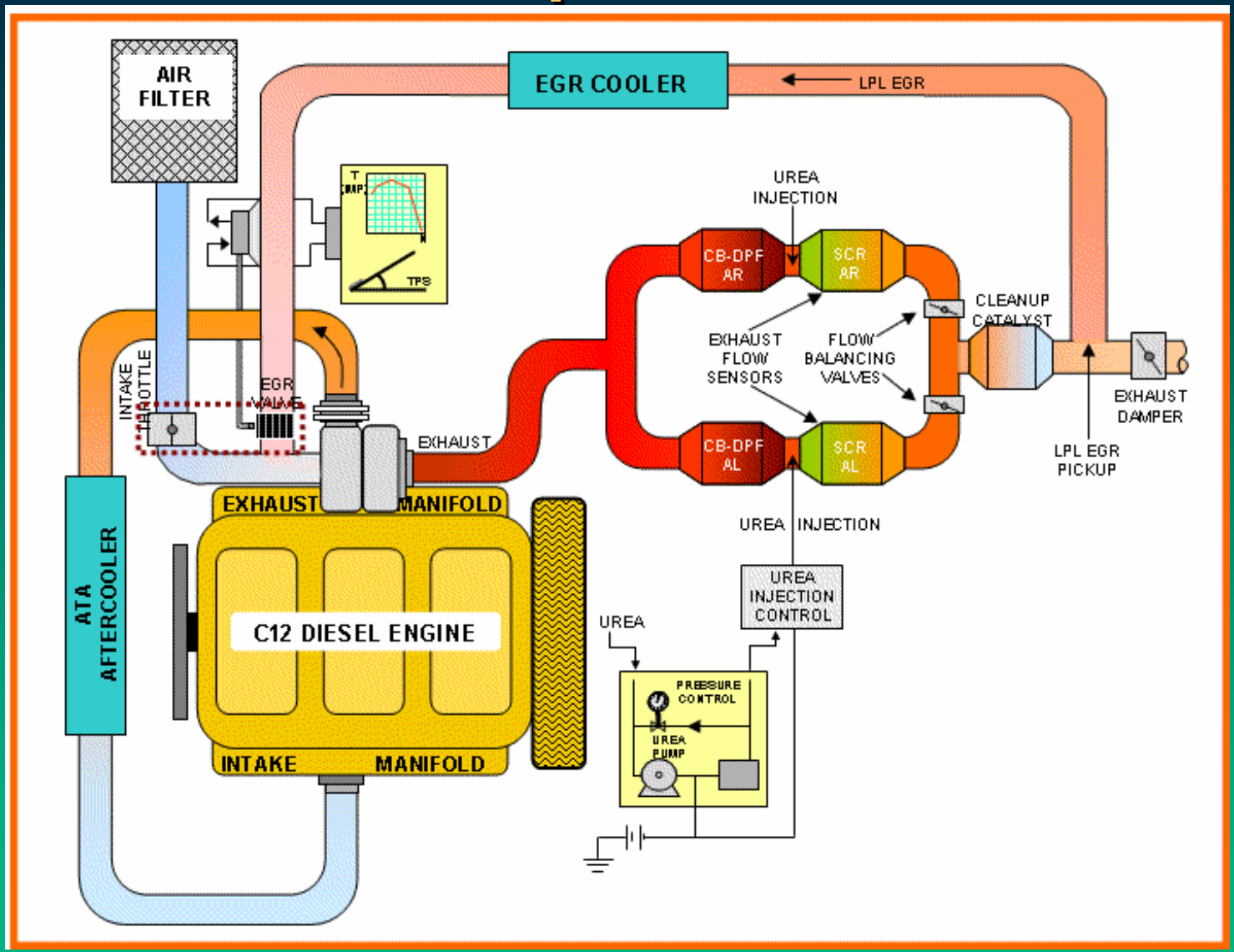
Engines:
Caterpillar
Cummins
Detroit Diesel
EMA
International Truck & Engine
John Deere
Mack Trucks

Technology:
Battelle

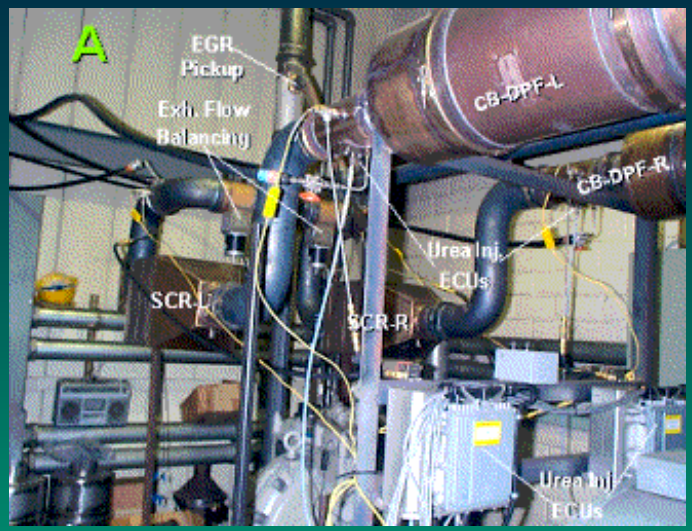
Emission Control:
Argillon
ArvinMeritor
Benteler
Clean Diesel Tech.
Corning
Delphi
Donaldson Co.
Engelhard
Johnson Matthey
MECA
NGK
Rhodia
Robert Bosch Corp.
STT Emtec AB
Tenneco Automotive
3M
Umicore

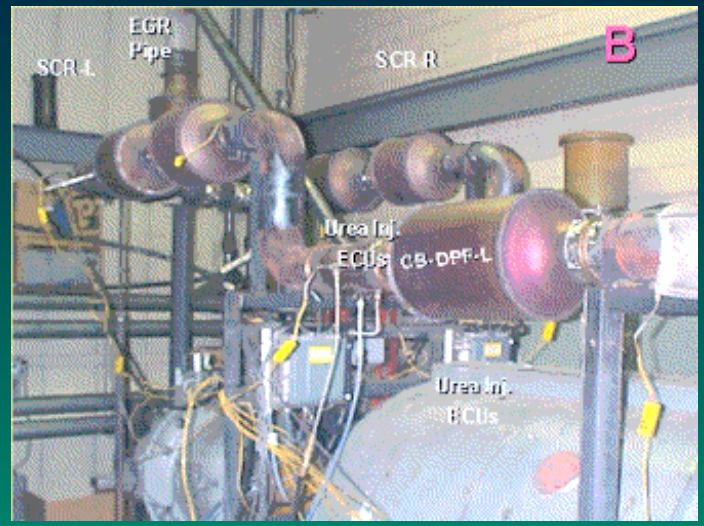
Energy/ Additives:
American Chemistry Council
API
BP
Castrol
Chevron Oronite
ChevronTexaco
Ciba
Conoco-Phillips
Crompton
Ergon
Ethyl
ExxonMobil
Infineum
Lubrizol
Marathon Ashland
Motiva
NPRA
Pennzoil-Quaker State
Shell Global Solutions
Valvoline

Test Setup - Schematic



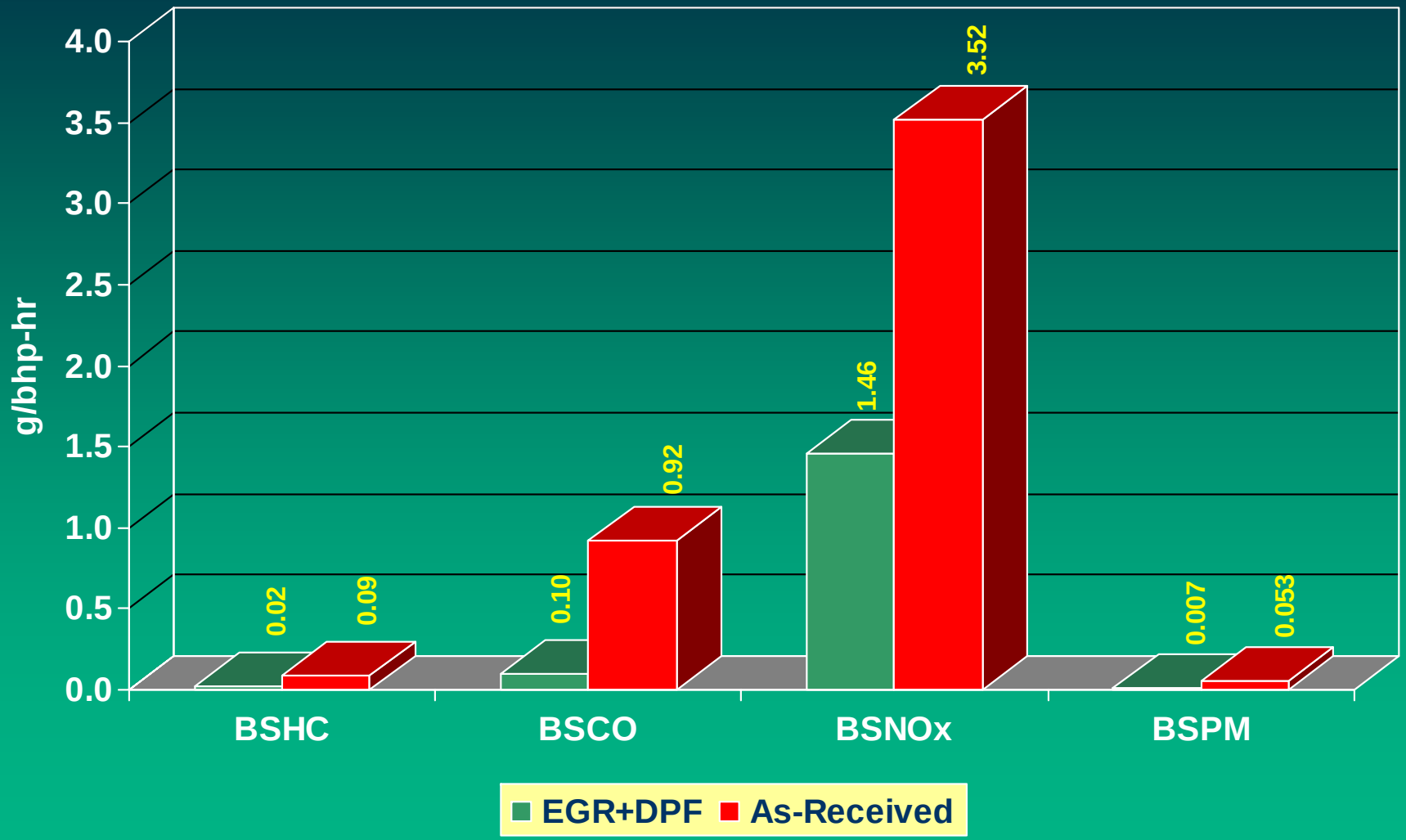
Aftertreatment Systems - Systems A & B



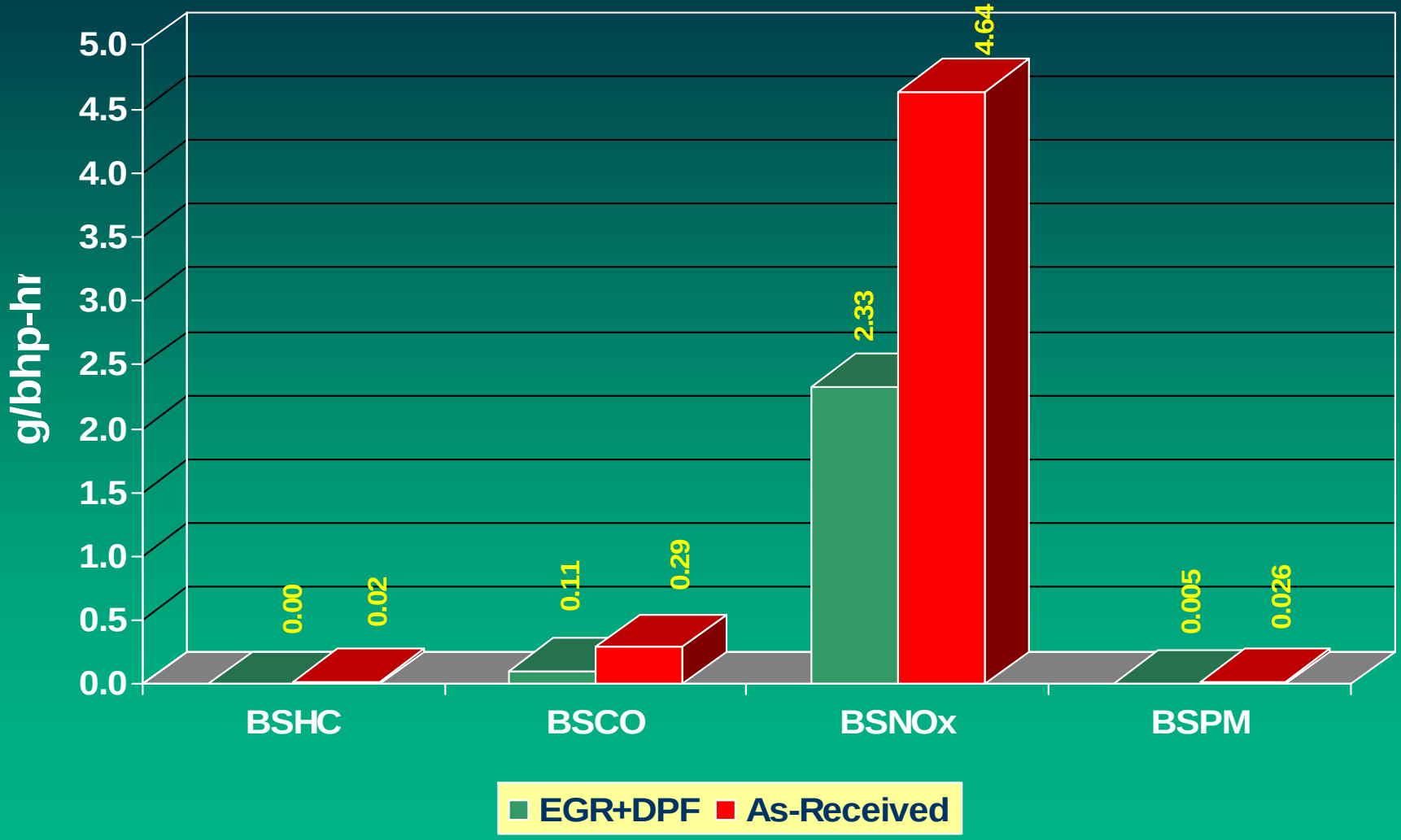


	No. of Units		Volume, L		Syst. Vol./Eng. Displ.		Remarks	
System	A	B	A	B	A	B	A	B
DPF	2	2	45.6	34.1	3.8	2.8	11.25X14”	10.5X12”
SCR	2	4	39.4	31.0	3.3	2.6	-	-
CUC	1	1	8.5	8.5	0.7	0.7	-	-
	-	-	93.5	73.5	7.8	6.1	-	-

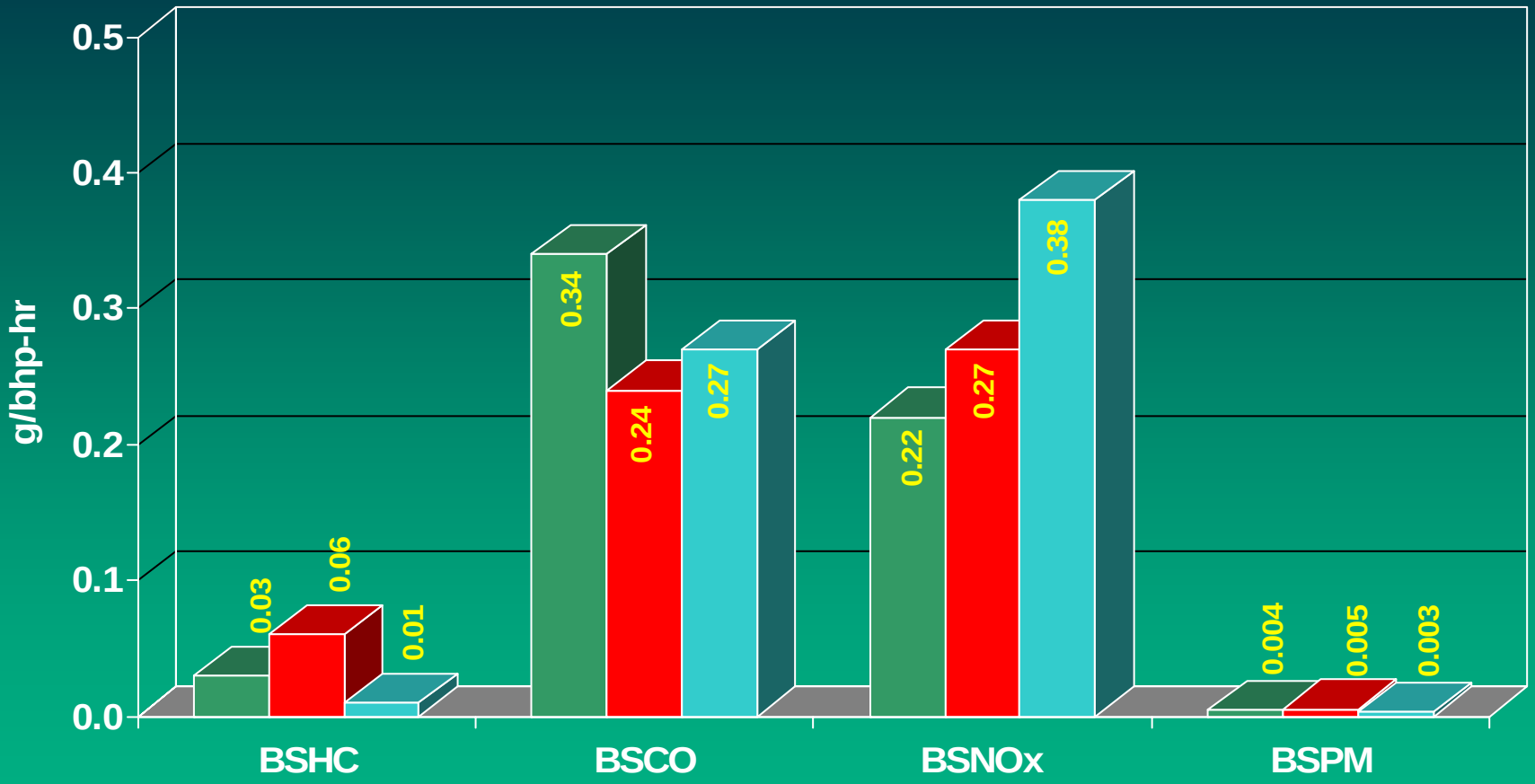
Transient Emissions Comparison
As-Received vs EGR + DPF -- DECSE 8 ppm Fuel



Steady-State Emissions Comparison
As-Received vs EGR + DPF -- DECSE 8 ppm Fuel



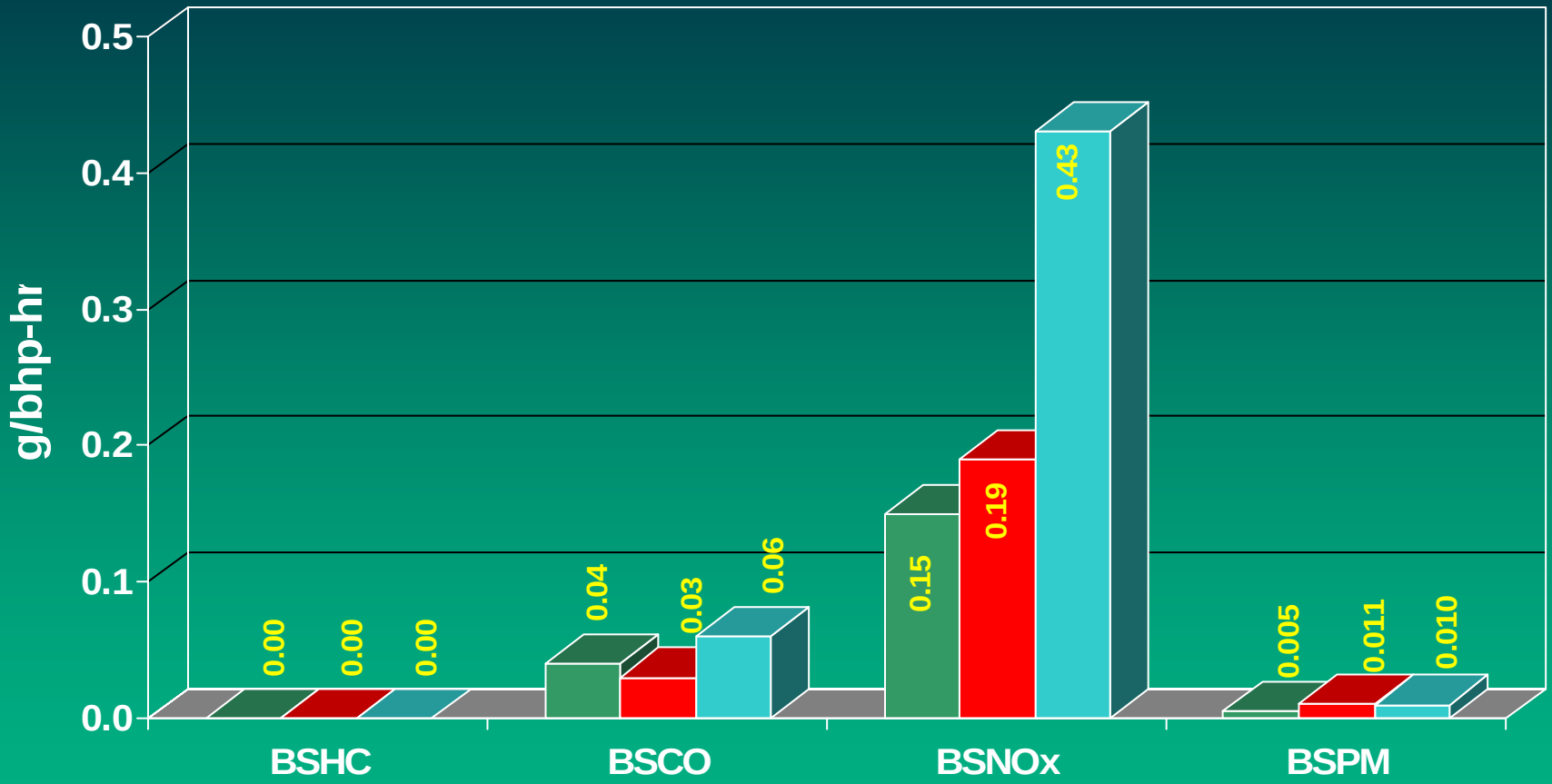
Transient Emissions Comparison
DECSE 8 ppm Fuel
10-200-2000 Hours Composite for System A



200-hr and 2000-hr tests are after engine failure and repair

** Urea dosing system problem*

Steady-State Emissions Comparison
DECSE 8 ppm Fuel
10-200-2000 Hours Composite for System A

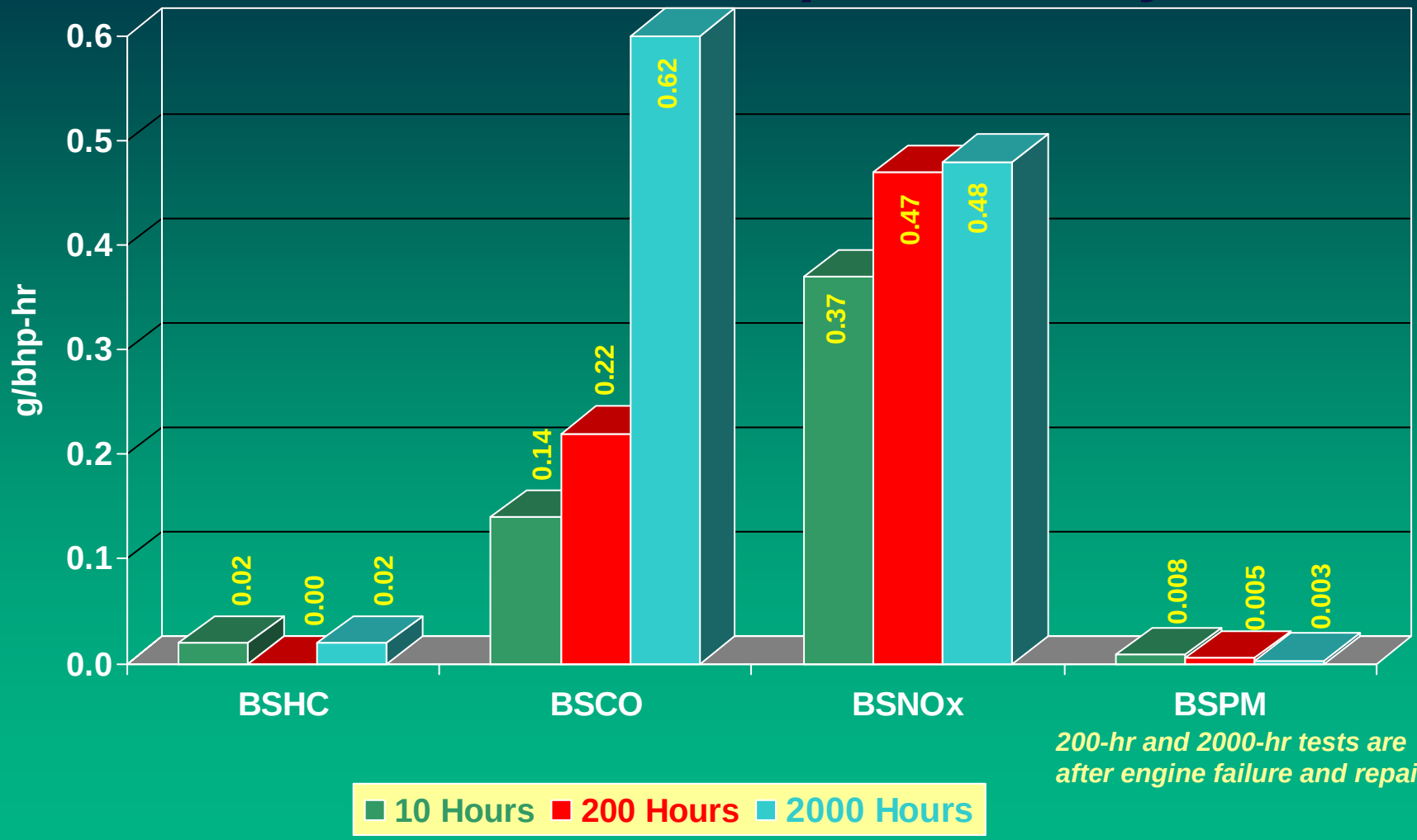


Average of 2 ESC Tests

200-hr and 2000-hr tests are after engine failure and repair

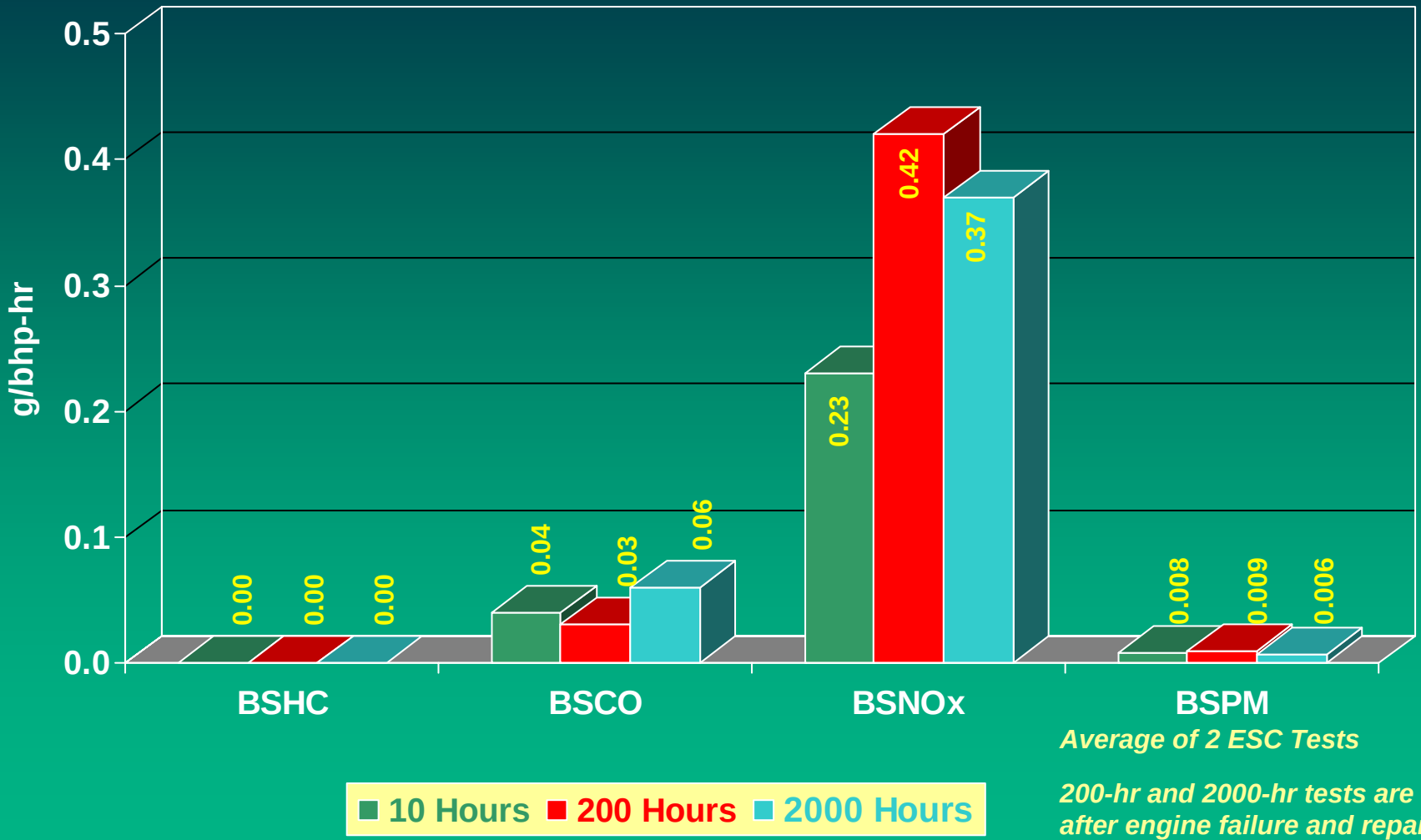
** Urea dosing system problem*

Transient Emissions Comparison
DECSE 8 ppm Fuel
10 – 200-2000 Hours Composite for System B



200-hr and 2000-hr tests are after engine failure and repair

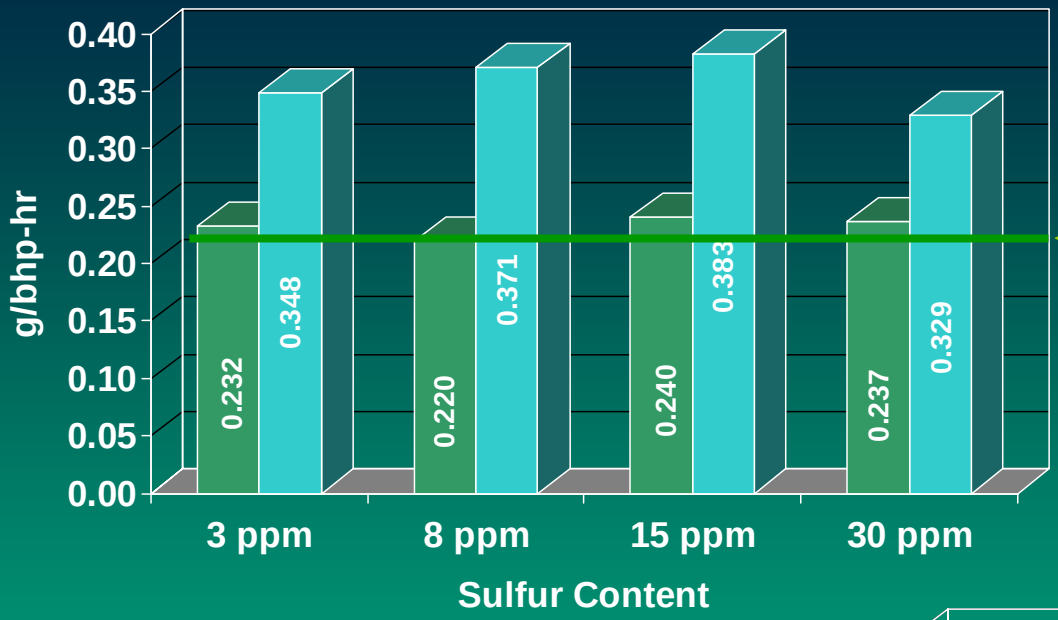
Steady-State Emissions Comparison
DECSE 8 ppm Fuel
10 – 200-2000 Hours Composite for System B



Average of 2 ESC Tests

200-hr and 2000-hr tests are after engine failure and repair

Sensitivity To Fuel Sulfur
Transient Emissions
Cold and First Hot Composite at 10 Hours

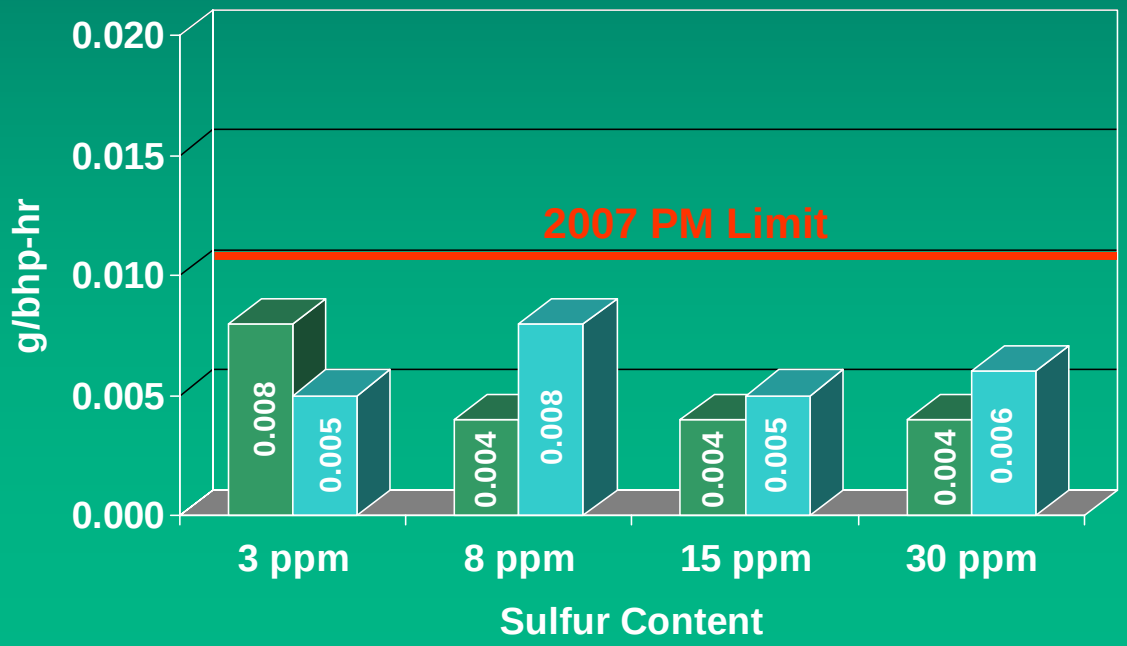


Target NO_x Limit

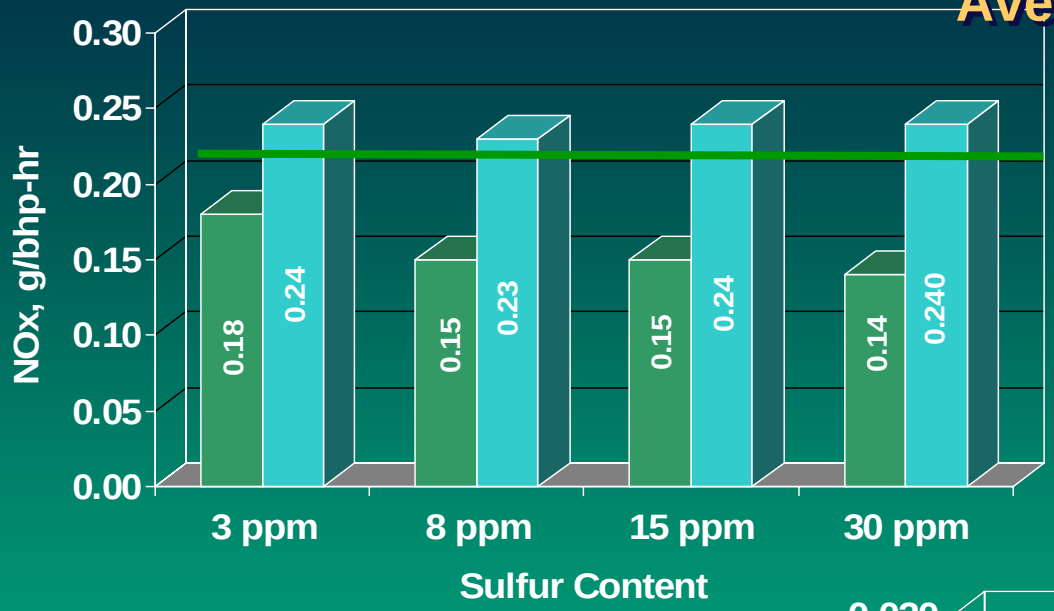
** Composite Based on Cold + First Hot-Start EPA Transient Tests*

System A

System B



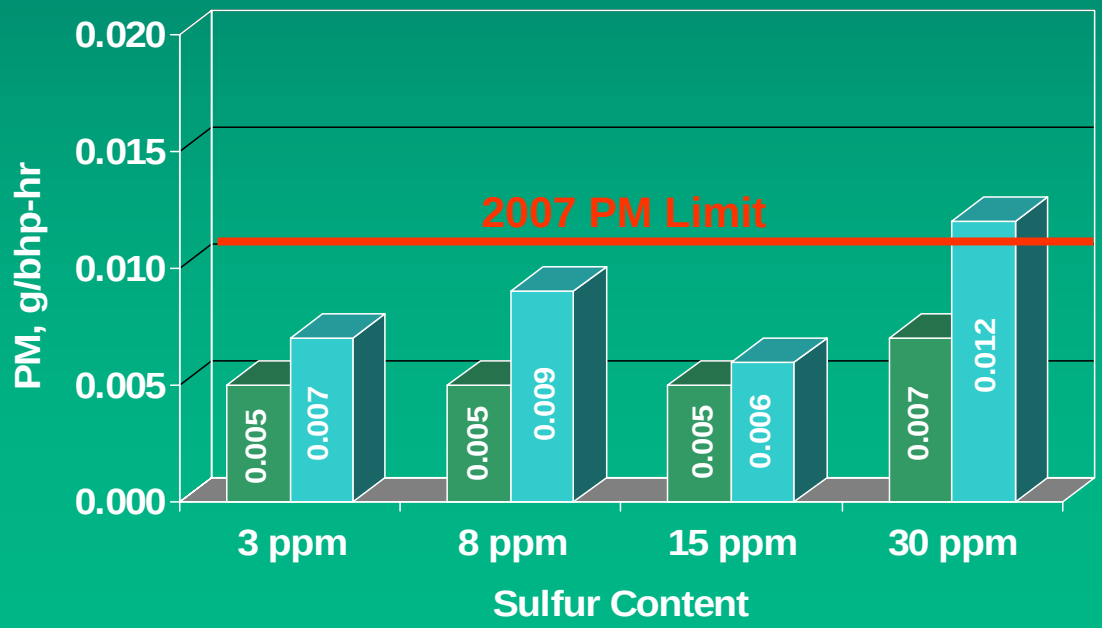
Sensitivity To Fuel Sulfur
Steady-State Composite Emissions
Average of 2 OICA Tests at 10 Hours



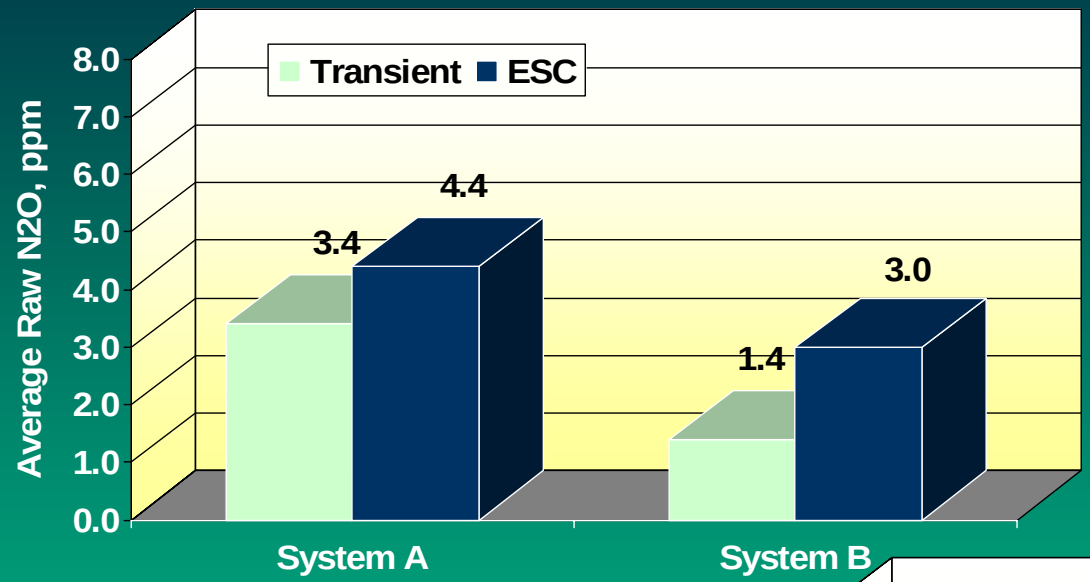
Target NO_x Limit

System A

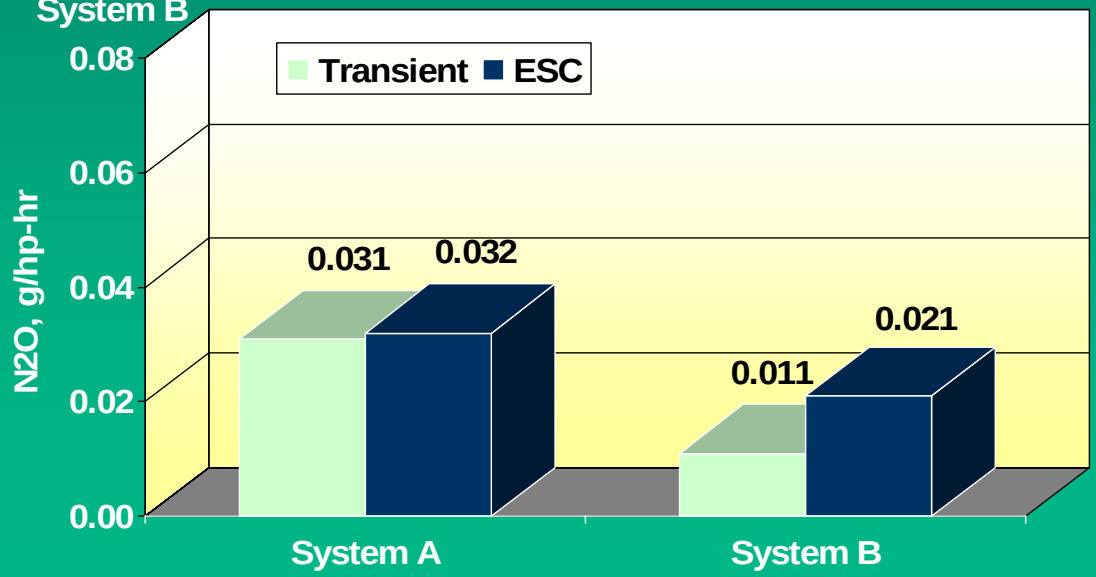
System B



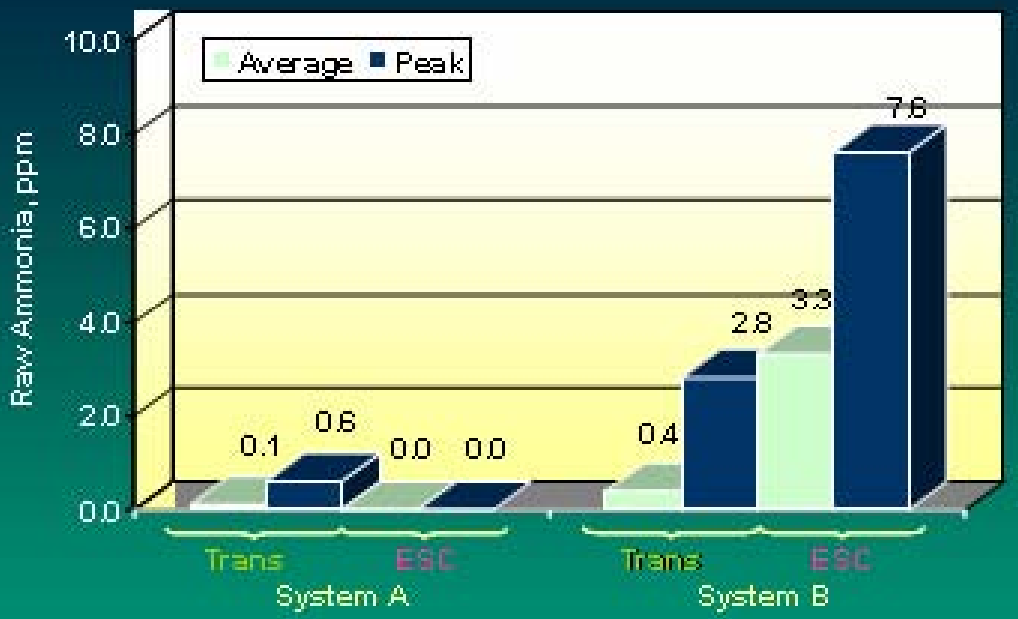
Nitrous Oxide Steady-State & Transient At the 2000-Hour Point

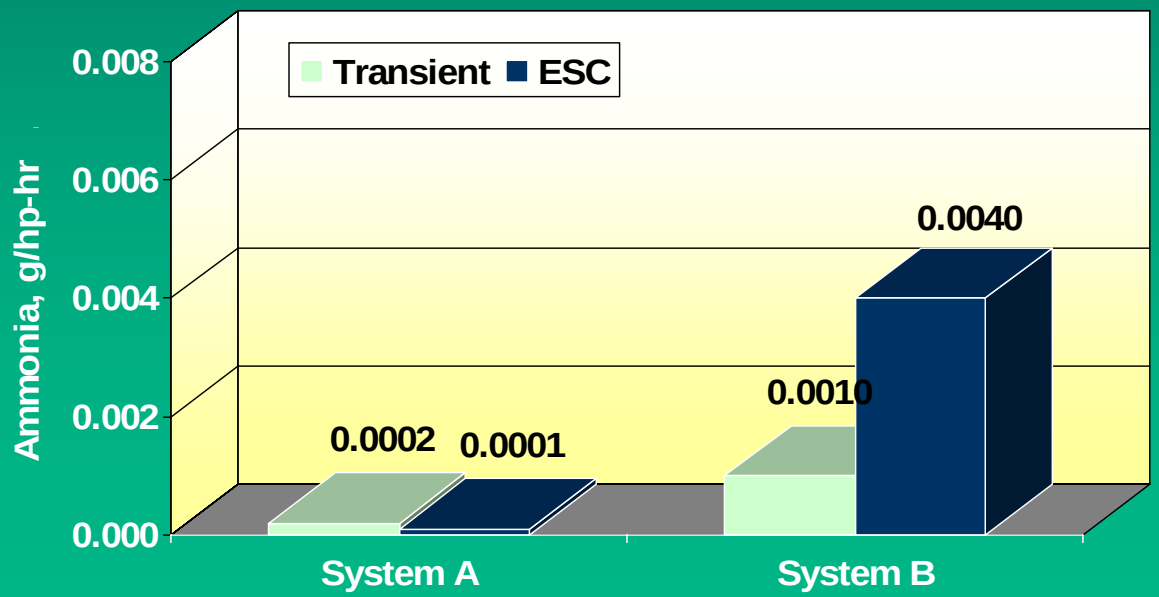


N_2O levels are roughly 10% of tailpipe NO_x level



Ammonia Slip Steady-State & Transient At the 2000-Hour Point





Fuel and Urea Consumption

- Transient BSFC increase of roughly 2% (+/- 1%) vs Base Engine
  - No significant increase due to EGR+DPF
- ESC BSFC increase of roughly 4-5% vs Base Engine
  - Most, if not all of the increase is due to EGR+DPF
- Urea Consumption as percentage of fuel consumption
  - System A ~ 1.8% transient and ~ 3.8% ESC (all +/- 0.2%)
  - System B ~ 1.4% transient and ~ 3.2% ESC (all +/- 0.2%)
  - Consumption increased after engine failure to compensate for higher engine-out NOx

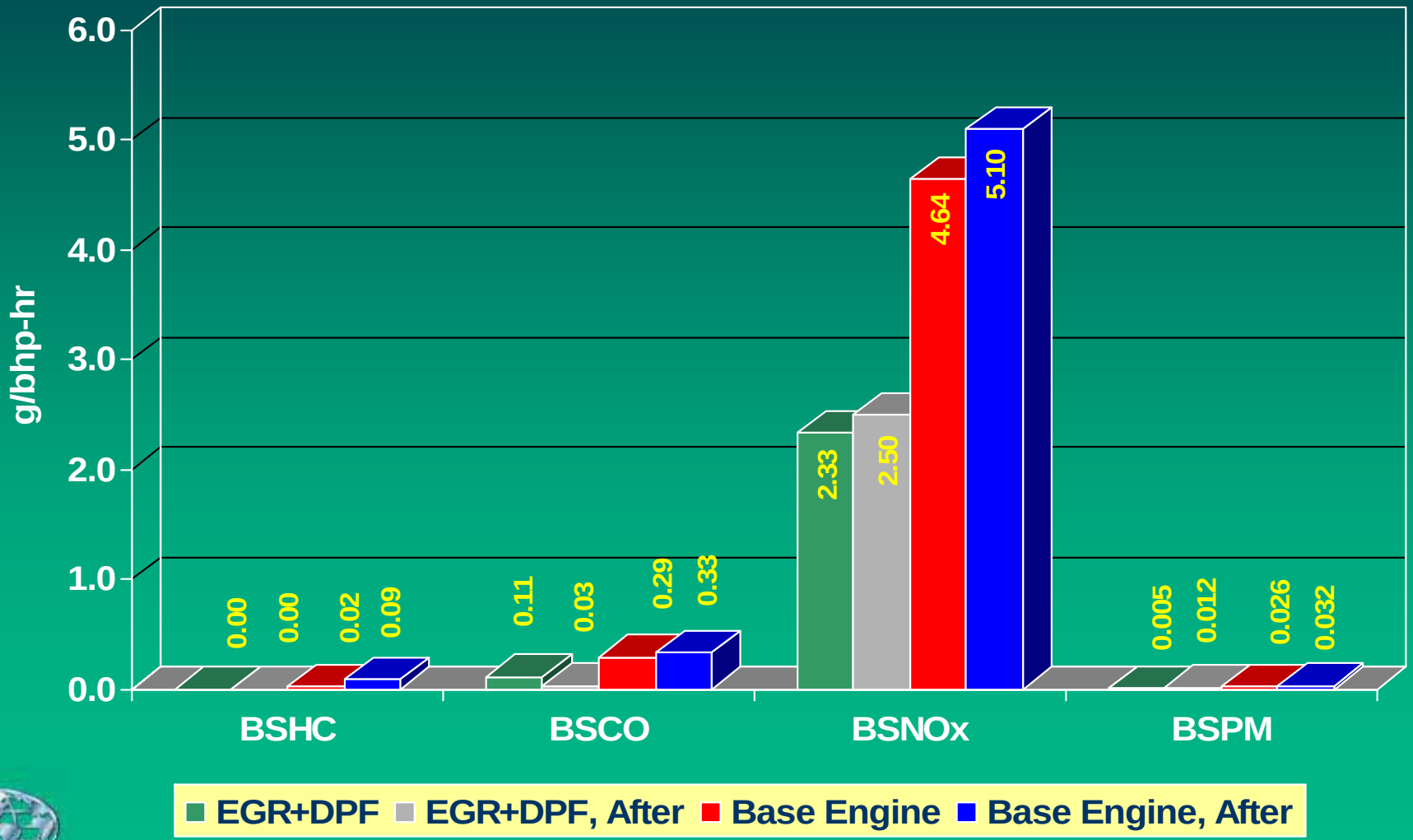
Summary/Conclusions

- Phase 1 is complete.
- Phase 2 started in December 2003.
- Both Systems have completed the 2000-hour performance evaluation

- Systems A and B are showing some performance differences mostly based on their size relative to that of the engine displacement.
- After 2000 hours SCR catalyst performance appears to be holding in general.
- After 2000 hours DPF performance is still good.

- It appears that this combination of technologies has the potential to meet the 2010 emissions limits
- Closed Loop Controls are essential to maintain 2010 emission levels

Steady-State Emissions Comparison
Base Engine vs EGR + DPF
DECSE 8 ppm Fuel
Before and After 200-hr Engine Failure



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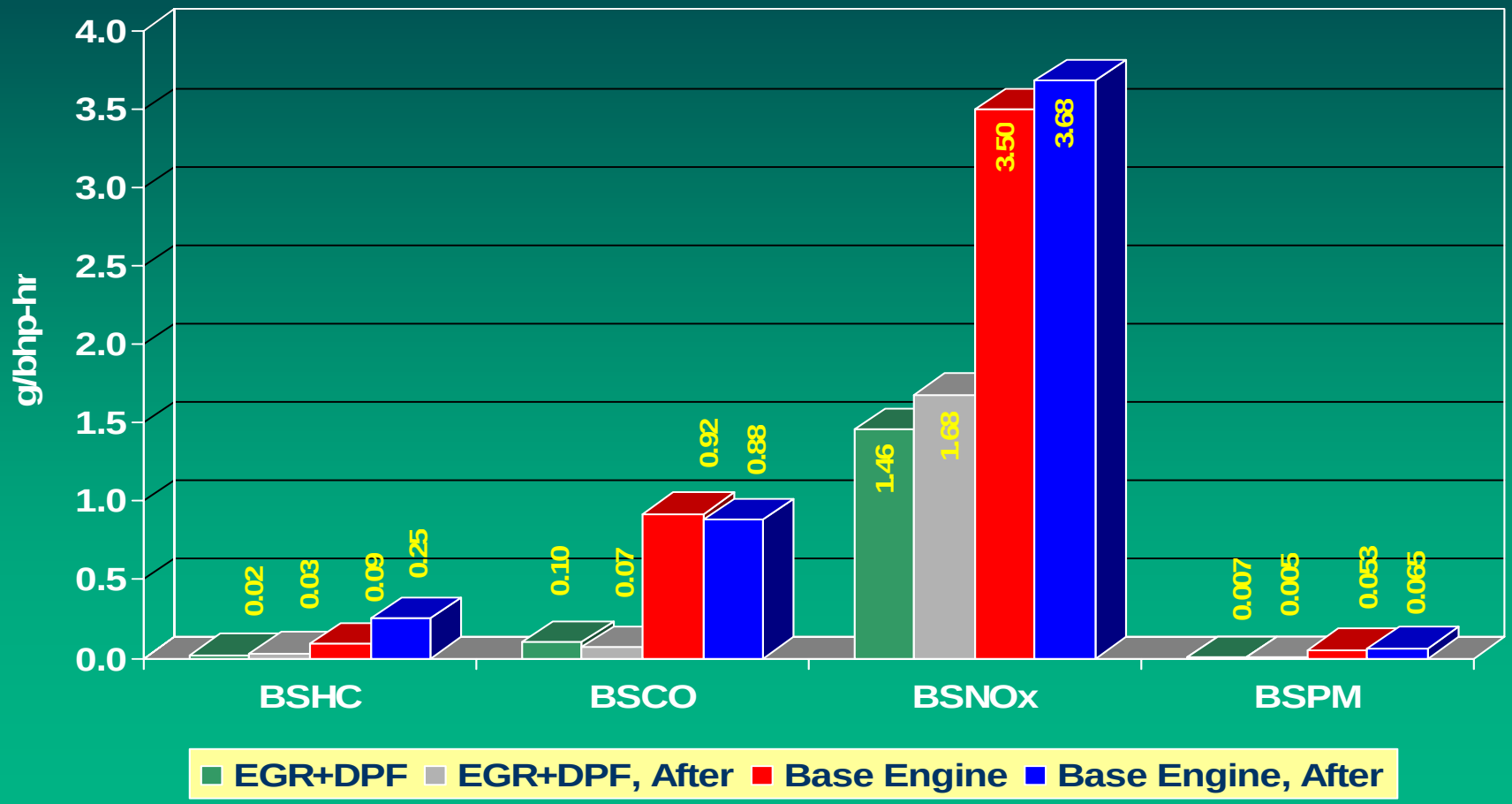

SCR Conversion Efficiency Before and After 200-Hr Engine Failure DECSE 8 ppm Fuel

	System A		System B	
	Before Failure	After Failure	Before Failure	After Failure
Hours on System	10	200	10	200
Transient Composite				
EGR+DPF	1.46	1.68	1.46	1.68
EGR+DPF +SCR	0.23	0.27	0.37	0.47
SCR Conversion, %	**84%**	**84%**	**75%**	**72%**
ESC Composite				
EGR+DPF	2.33	2.50	2.33	2.50
EGR+DPF +SCR	0.15	0.17	0.23	0.42
SCR Conversion, %	**94%**	**93%**	**90%**	**83%**